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ANALYSIS OF INFORMATION SYSTEMS ON THE BASIS OF AUTOMATIC CONTROL THEORY

by

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13. ABSTRACT

An idealized, strongly simplified information system is studied on the basis of the theory of automatic control. The primary advantage noted for the apparatus of the theory of automatic control is its universality, that is the ability to apply this theory to various material systems.

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The development of information systems in our country and the increased complexity of the tasks which they must perform have resulted in increased interests in the study of these systems. Primary attention is being given to problems of optimization of the operation and control of information systems. Relatively few works are dedicated to the study of information processes and determination of the regularities of their behavior. The great experimental and practical material which has been accumulated up to the present in the area of organization of scientific and technical information amounts unfortunately primarily to verbal descriptions and in many cases to purely intuitive judgements. This fact forces us to seek means by which the investigation of information systems could be formalized and given the necessary accuracy.

It is probable that this problem could be solved most fruitfully on the basis of the ideas of cybernetics, and particularly using the theory of automatic control.

This theory, as one branch of the scientific apparatus of cybernetics, is applied not only in technology [1], but in living organisms and in society: in biology [2], physiology [3], bionics [4], sociology [5] and economics [6]. The ideas of the generality of control processes were first formulated, as we know, by N. Wiener.

Thus, the basic advantage of the apparatus of the theory of automatic control is its universality; that is, the possibility of its application to various material systems.

The correctness of the cybernetic approach to the study of information systems is also determined by the specifics of their structure. They most clearly show "three fundamental phenomena, within the framework of the unity of which modern cybernetics is formulated and developed as a science," [7]:1) the capability for perception, storage, processing and utilization of information; 2) the possibility of conversion of the system from one state to another as a result of transformation of information; 3) the presence of a given level of organization of the system itself.

Although these specifics determine, as we have noted, the possibility of application of the well developed apparatus of the theory of automatic control to information systems, a number of other specific features of scientific and technical information limit this possibility.

The most important of these is that there is still no acceptable criterion for qualitative and quantative evaluation of information streams, significantly hindering their study and comparison [8].

A second specific feature is that the development of information systems is based on the development of science, productive forces and the actions of economic laws. This means that information systems are complex systems, distinguished by great variety of control actions, communications channels and perturbations.

Finally, the various levels of information systems and their position in the structure of the national economy are characterized by a hierarchical nature and complexity of interrelationships between individual elements of these objects.

Thus, these specifics explain to some extent the difficulties with which we must deal in studying information systems on the basis of methods of the theory of automatic control. However, together with this, the use of the basic concepts and scientific tools of the theory of automatic control opens the possibilities for deeper analysis, calculation and study of information systems; mathematical models can be constructed, and control policies revealed on the basis of these models, providing for the desirable effectiveness and reliability of systems.

The construction of mathematical models is not only a theoretical, but also of practical significance. The cybernetic approach to the analysis of information systems allows us to answer many important questions of the leadership and planning of information processes. What will occur in a system when the control actions or perturbations are changed? Will the deviation of the information process from a fixed process be extended or brief? What forms of control must be selected for stabilization of the system and its reduction to optimal functioning? The answer to all these questions, produced by means of the theory of automatic control, allows us to evaluate and understand the problems and methods of testing and control of scientific and technical information systems from a different angle and to bring some order into the mass of experimental results available.

We must note that the mechanism for testing and regulation, expressed in the mathematical form of the theory of automatic control, is broadly used in principle in the practice of administration of information systems. For example, under real conditions, using data on the actual status of various systems, decisions are always made, the purpose of which is to improve the system. However, knowledge of the scientific principles of the functioning of the system, the cause and effect dependences of its individual elements, allows us to make correct decisions, avoiding errors in control and increasing the total reliability of the system.

Thus, cybernetics arms information workers with the knowledge necessary for scientific control of information systems. In this connection, we would like to recall the words of G. Klaus: ...The history of science teaches us -- which we should not forget -- that when already known facts and relationships can be reformulated within the framework of new, more general theories, something greater than simple repetition of old facts in new surroundings is almost always achieved" [9].

Analysis and synthesis of systems in the theory of automatic control are based on higher mathematics and consist in the investigation of rather complex differential equations. We will attempt to avoid detailed proof of the equations presented, and will base ourselves on simple formulas and graphs, in order to avoid distraction from our discussion on the one hand and to avoid losing the general idea of the method of investigation in the complexity of its mathematical apparatus. This article does not pretend to give an answer to all problems arising concerning the relationship of informatics with the theory of automatic control; its purpose is rather to stimulate specialists to think about certain problems in the application of the theory of automatic control to the investigation of information systems. Our hopes for the proper approach to this problem indicate to us that the considerations which we state here will be refined, developed and supplemented.

1. Preliminary Considerations.

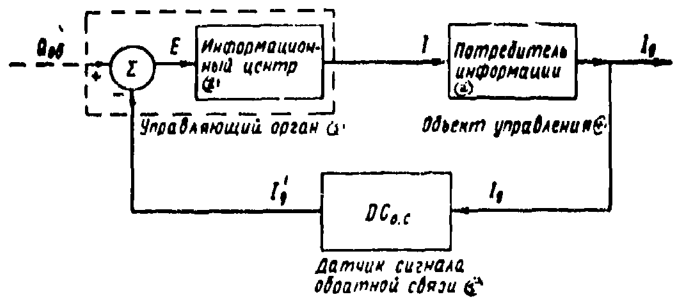
The application of the theory of automatic control to the investigation of information processes will be illustrated on the example of an actual system consisting of an information center and an information consumer. This system frequently a part of a more general information system, has been selected, since it is at this level of control that we feel many of the basic regularities of information processes can be found.

The interrelationship between the two material objects "information center" and "information consumer" consists in the maximum satisfaction of the interests of consumers for information by current (initiative) information and by outputting responses to requests. As D. Ye. Shekhurin [10] noted correctly, "...Consumer usually expresses in the form of requests only that portion of his requirements which goes beyond the framework of his constant information support. This portion is less, the more reliably and effectively the operating system of information servicing works."

Thus, a knowledge of the objective requirements for information and an ability to satisfy this demand fully allows the information center to create a reliable system of information support of consumers and to influence the formation of the flow of requests actively.

Let us study the interaction of the control organ (information center) with the object of control (information consumer), based on the reference information services of consumers. A functional diagram of this system is shown on Fig. 1. Let us assume that initiating action Q_{ob}, an objective requirement for information, arrives at the input of the system. This parameter can be expressed by a certain quality of requests, the responses to which by the information system fully satisfies the production-technical or scientific demands of the consumer. The output signal from the system

-- variable I_g -- represents that portion of information, using which various specific tasks can be performed.



KEY:

1. Information Center
2. Information Consumer
3. Control Organ
4. Object of Control
5. Feedback Signal Sensor

Fig. 1. Functional Diagram of Information System, Describing Servicing of Requests by Consumers by Information Organ: Q_{ob} Starting Action; E Error Signal; I Control Action; I_g Actual Output Signal; I'_g Feedback Signal; DC_{OC} Feedback Signal Sensor; (Not Present as an Actual Independent Element in the System; Measurement Functions are Performed at the Information Center).

Signal I_g can be expressed by a certain number of responses of the information center, fully satisfying the requirements of the consumer.

Let us further assume that the information center at each stage of control determines the difference between the number of requests (objective requirement), Q_{ob} and the number of responses I_g, satisfying the consumer. In this case, the true output signal is transmitted through a feedback channel in the information center, where it is continually compared with the initiating action. As a result of the difference (error) between these signals $E=Q_{ob}-I_g$, control action I is formed. Signal I represents specific suggestions (capabilities) of the information center, expressed in the number of positive responses to consumer requests, and is directed toward maximum satisfaction of information requirements.

As we have already noted, the purpose of control by the information center is to convert the status of the system output to a fixed norm, that is to $I_g=Q_{ob}$. Obviously, in order to fulfill this task control action I must act on the object of control during the entire interval of time that the error differs from 0.

We must note here an important principle of feedback -- the control principle, allowing us to change the dynamic properties of the system and thereby improve the quality of the process of regulation.

Unfortunately, under actual conditions the feedback allowing us to calculate the effectiveness of the reference information service is insufficiently utilized by information organs. In [11], dedicated to analysis of information requirements, the following noteworthy conclusion was drawn: "the existing information support system both of entire collectives and of individual specialists clearly makes insufficient use of feedback from the consumers: Information is sent only through one channel -- from source to consumer -- while the evaluations, useful as they would be, are generally not received by the information service."

We should add to this conclusion that in practice many information centers eliminates errors in the operation of the reference information service system only when complaints are received from information consumers.

In conclusion to our introductory section, we might present a simple calculation determining the numerical indicators of the system outlined above.

Suppose solution of a specific production problem requires 100 requests. Consequently, the objective information demand $Q_{ob}=100$. Let us assume that the information center answers to only 50 requests ($I=50$). Let us further assume the frequently encountered case when only a portion of the responses of the information center satisfy the consumer, for example, half ($I_g=25$)[1].

Based on the assumptions which we have made, the information center is not performing the task of satisfying the requirements of the consumer for information. Therefore, in correspondence with the control program which we have formulated, the information center, as a regulator, should introduce the correction copy $E=Q_{ob}-I_g=100-25=75$, which, with the same through put capacity of the system, should approximate the value of the output signal I_g to the fixed norm $Q_{ob}=100$. It is easy to see that in the example which we have cited, we have assigned arbitrary values to through put capacity of the system, input and output signals, not considering their dependence on time, and therefore our discussions do not reflect the dynamics of an actual existing system.

Let us now go over to the problem of analysis of the dynamics of the system, related to the study of the characteristics and behavior of the system as functions of time and the values of parameters. We recall that the analytic methods of study of dynamics relate to the theory of differential equations and the theory of Laplace transforms.

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1 It is expedient here to note the characteristic observation: "...It is interesting to note that the quantity of documents found relevant from the point of view of the information retrieval system is not always "relevant" for the consumer. In other words, under practical conditions the consumer frequently selects from the total number of documents output by the information retrieval system only those which are actually useful to him" [12].

II. Dynamics of the "Information Center - Information Consumer" System.

First, let us study the dynamics of the individual links, then of the system as a whole.

The control organ (2, a). Suppose the intensity of arrival of a certain quantity of requests to the subsystem "information center" is characterized by E(t), the output by the number of positive responses I(t). In the formal respect, the problem is reduced to that of analytically relating the parameters of this link with respect to time, that is describing the phenomena occurring in it, by differential equations.

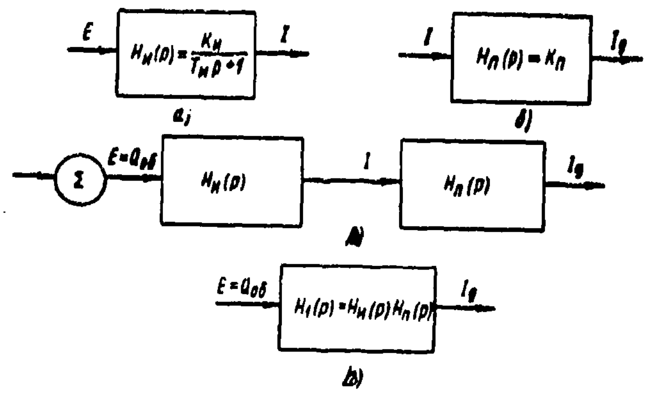

Fig. 2. Structural Diagram of the Open System: a. Diagram of Information Center; b. Diagram of Information Consumer; c. Initial Open System Consisting of Two Links; d. System Transformed to One Equivalent Link.

A full mathematical description of this link is quite difficult due to its nonlinearity. This arises as a result of many factors: disruption of the technological process of responding to requests, shortages of personnel, errors in filling out documents, poor organization of work, etc. All of this distorts the linear nature of the mode of processing requests and preparation of responses to them. However, in order to improve our understanding of the dynamics of the information center, it seems expedient to simply it and represent it as a first order system.

In preparing a mathematical description of the control organ, we will base ourselves on the formalized process of functioning of the information center. Let us assume that the information center satisfies only a portion of the requests which it receives[1]. In this case we can write

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[1] The division of responses to requests into only two levels (relevant documents "provided" or "not provided") is actually quite oversimplified. However, in the problem at hand this is permissible within the limits of the generality of the conclusions we shall draw concerning the operation of the information center.

$$I(t) = E(t) - R(t) \quad (1)$$

or

$$E(t) = I(t) + R(t), \quad (2)$$

where E(t) is the number of requests at moment t; I(t) is the number of positive responses at moment t; R(t) is the number of unsatisfied requests (negative responses) at moment t.

In an elementary time unit dt, the information center receives Edt requests. These requests will be transformed into responses. With a request processing time of A_{min}, only AdI positive responses will be produced. Assuming that the number of negative responses is proportional to the instantenous value of I, that is

$$R(t) = \alpha I(t), \quad (3)$$

we can produce the number of negative responses, equal to αIdt. The proportionality factor α depends on the structure of the information center files. The more thematically and quantitatively the composition of the files are represented, the more positive responses can be produced and, consequently, the lower he value of factor α.

Based on the equations (2) and (3), we can write

$$Edt = AdI + \alpha Idt,$$
$$\frac{A}{\alpha} \cdot \frac{dI}{dt} + I = \frac{E}{\alpha}.$$

Representing

$$\frac{A}{\alpha} = T_{\text{и}} \text{ and } \frac{1}{\alpha} = k_{\text{и}},$$

we produce the equation for the subsystem

$$T_{\text{и}} \frac{dI}{dt} + I = k_{\text{и}} E. \quad (4)$$

Relationship (4) is a linear, homogeneous, first order, first power differential equation, characterizing the operation of the information center, i. e., determining the number of positive responses as a function of changes in the number of requests at the input of the subsystem. Due to the similarity of equation (4) to the equation of a linear continuous operating link studied in the theory of automatic control [1], the information center can be represented in the dynamic aspect as a first order inertial link.

Replacing the operation of differentiation of equation (4) with the Laplace operator p and variable (t) with the complex variable (p), following the corresponding transformations, we produce the transfer function of the subsystem "information center," which will be

$$H_{\text{и}}(p)=\frac{I(p)}{E(p)}=\frac{k_{\text{и}}}{T_{\text{и}}p+1}. \quad (5)$$

where $k_{\text{и}}=1/\alpha$ is the transfer factor of the link, characterizing the capabilities, the "response" of the information organ; α is a proportionality factor, depending on the theme and completeness of the library files; $P_{\text{и}} = A/\alpha$ is the time constant of the link, characterizing the inertial factor of the information organ; A is the request processing time, dependent on the operating speed of the information retrieval system used and the information search method used; p is a complex variable (operator); I(p) is the Laplace transform of function I(t); E(p) is the Laplace transform of function E(t).

Transfer function H (p) of the control organ fully defines the form of the dynamic characteristics of the physical subsystem "information center."

Writing differential equation (4) in operator form greatly simplifies all further calculations and investigation of the system.

Object of control. Let us study the dynamics of the second link -- the subsystem "information consumer" (Fig. 2, b).

Acting as the object of control, the information consumer evaluates all responses arriving from the information center critically. Following comparison of the responses with the objective requirements for information, the consumer either accepts them for utilization in its operation or "weeds out" that portion which does not provide the required solution of a given problem.

Obviously, the time expended by the consumer in evaluating the response T_π is several times shorter than the time required to service a request A in the information center.

If we accept this condition ($T_\pi \leq T$), than the inertia of the control object can be ignored with sufficient accuracy for practice, i. e., we can consider that $T_\pi = 0$ and study the subsystem "information consumer" as a non-inertial link. Then the transfer function of the information consumer will be

$$H_\pi(p)=\frac{I_{\text{в}}(p)}{I(p)}=k_\pi. \quad (6)$$

where k_π is the transfer factor of the link.

Relationship (6) shows that input signal I is transmitted to the output without any delay and that its value at each moment in time is proportional to the input quantity: $I_g(t)=k_\pi I(t)$.

Combining the transfer functions of the control organ (5) and object of control (6), we produce the transfer function of the open system "information center -- information consumer," consisting of two series -- connected first order links (Fig. 2, c, d):

$$H_1(p) = H_u(p) \cdot H_n(p) = \frac{I_g(p)}{E(p)} = \frac{I_g(p)}{Q_{o6}} = \frac{k_u k_n}{T_u p + 1} = \frac{k_1}{T_u p + 1}, \tag{7}$$

where $k_1 = k\ k_\pi$ is the transfer factor of the open system.

The transfer function $H_1(p)$ of the open system defines the dependence of output signal I_g on signal $E = Q_{ob}$.

The "information center - information consumer" system. Since according to the conditions which we accepted earlier, the task of the information center includes checking the actual number of responses I_g accepted by the information consumer and comparison of this quantity to the assignment (objective requirement Q_{ob}), the system must be given a feedback loop.

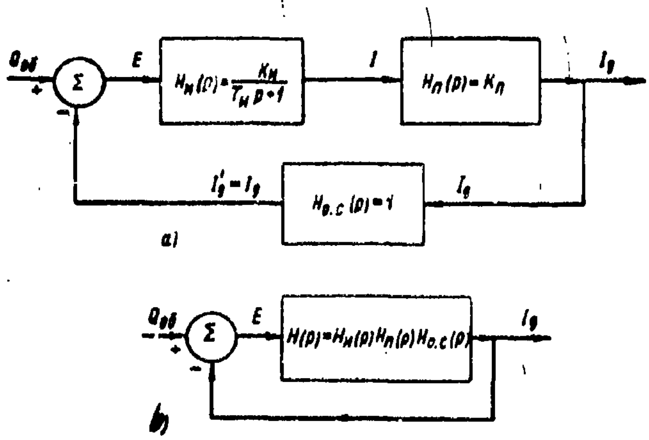

Fig. 3. Structural Diagram of Closed System: a. Initial System; b. System Transform to One Equivalent Link.

A structural diagram of the closed "information center - information consumer" system is shown on Fig. 3. The actions of the information center returned through the feedback loop, are described by the transfer function

$$H_{oc}(p) = \frac{I'_g}{I_g} = 1. \tag{8}$$

Relationship (8) means that a change in the output signal I_g is recorded and modeled at the information center instantenously, without delays, that is that $I'_g = I_g$. Here once more for simplification we reduce the order of the equation of the feedback loop, although in the general case the time constant of this link is not eual to 0 (the transfer function here apparently should be $H_{oc}(p=e^{-p1})$, corresponding to the dynamics of a delaying link).

The transfer function of the closed system, considering that

$$I_g(p) = H_1(p)E(p) = H_1(p)\left[Q_{ob}(p) - I'_g(p)\right] \text{ и } I'_g = I_g, \text{ и } H_{o.c} = 1,$$

will be

$$H(p) = \frac{I_g(p)}{Q_{ob}(p)} = \frac{H_1(p)}{1 + H_1(p)} = \frac{\frac{k_1}{T_n p + 1}}{1 + \frac{k_1}{T_n p + 1}} = \frac{k}{Tp + 1}, \tag{9}$$

where

$$k = \frac{k_1}{1 + k_1}; \quad T = \frac{T_n}{1 + k_1}.$$

Transfer function H(p) of the closed system relates the instantaneous actual number of responses accepted by the consumer I_g to the assignment, i. e., the objective requirement for information Q_{ob}.

Comparing equations (7) and (9), it is not difficult to see that when the system contains a feedback loop, we produce a first order inertial link, but the transfer factor and time constant are decreased by $(1+k_1)$ times.

Formalized relationship (9) fully sums up our mathematical description of the information process in the system "information center -- information consumer." Thus, equation (9) is a mathematical model of the system, determining the dependence of the characteristics of the status of the system on its parameters.

Transient characteristics of the system. Up to this point, we have based ourselves on the assumption that the flows of requests and responses are continuous, and the form of the signal involved has not interested us. Since in

actual systems the flows of requests and responses may differ in nature, it is necessary to know the reaction of the system to possible changes in the form of the defining action Q_{ob}.

Most interesting is a subchange in signal Q_{ob}, when the requirement for information suddenly increases relative to the expected or predicted value by Q_{o_o}, i. e., Q_{o_o} is a function of the jump. This change in demand for information creates the most difficult conditions for the operation of the system and therefore studies of the dynamics of the system in this case are of particular interest. We note that the sudden change in the value of Q_{ob} accepted here is well approximated, with accuracy sufficient for all practical purposes.[1]

The reaction of the system to a jump can be found directly using transfer functions (7) and (9), utilizing the method of the Laplace transform (intermediate calculations omitted): for the open system

$$I_p(t) = k_1 Q_{ob_0}\left(1 - e^{-t/T_H}\right), \ t > 0, \tag{10}$$

for the closed system

$$I_z(t) = kQ_{ob_0}\left(1 - e^{-t/T}\right), \ t > 0, \tag{11}$$

where Q_{ob_o} is the amplitide in the jump in signal Q_{ob}.

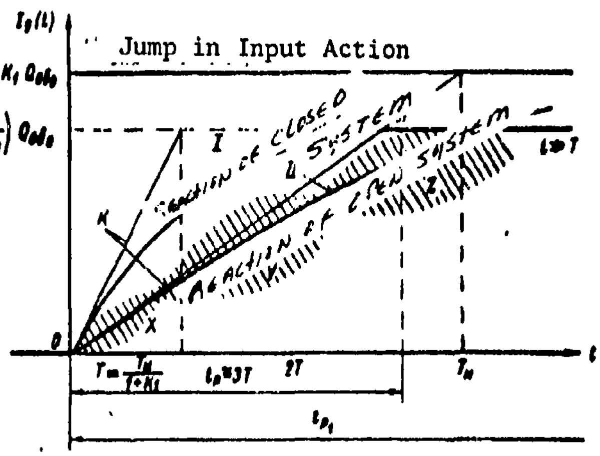

Fig. 4. Transient Characteristics of the System: 1. Characteristics of Closed System; 2. Characteristics of Open System.

[1] For example, in the Library of Congress of the USA, during some periods of time up to 1,000 requests are received each day, i. e., 5 to 6 requests each minute, or 1 request each 30 seconds [13].

Equations (10) and (11) determine the nature of the transient process in the system from the moment of application of constant input quantity in the form of the jump Q_{ob_0} to the moment of the new stable state. The transient characteristics for the open and closed systems are shown on Fig. 4. Due to the differences in the gain factors and time constants in equations (10) and (11), the dynamic properties of these systems become different.

III. Discussion of Results and Conclusions.

We recall that the time constant $T_{\text{и}}$ according to expression (5) is Λ/α, i. e. is proportional to the operating speed of the information retrieval system and the method of search for requests and inversely proportional to the structure of the information system files. Obviously, the value of $T_{\text{и}}$ will be less, the faster the retrieval system and the more refined the method of information search. On the other hand, the lower the value of α, i. e., the more representative the quantative and qualitative composition of the information file, the more complex its structure, the higher the value of $T_{\text{и}}$, characterizing the expenditures of time for servicing of requests.

The physical sense of $T_{\text{и}}$ and T become clear from the curves of the transient process (see Fig. 4). The value of $T_{\text{и}}$ shows the time during which servicing of a request would be completed if the rate of change of the output signal remained constant, equal to the rate of change of the signal at the initial moment in time. However, this initial rate does not remain constant, but rather damps exponentially. Therefore, the time of transient process T_{p1} of the open system, characterizing the actual length of servicing of requests, is approximately equal to 3 times the time constant: $t_{p1} \approx 3T_{\text{и}}$. This equation is also correct for the closed system $t_p = T$.

Thus, the duration of servicing of requests from the moment of their arrival at the information organ until the moment of output of responses into the communications channel to the consumer is lengthened by the inertial nature of the information organ. In practice, the delay in responding to requests can be explained by a number of factors.

In the preparatory stage (study and analysis of requests, their indexing, preparation of search descriptions) as a rule, significant deviations from the established operating mode do not arise and therefore the change in intensity of processing of requests is practically constant. This explains the nature of curve II in area X.

During the period of actual search and selection of relevant documents in the retrieval system, the normal course of processing of requests is disrupted to a greater extent. This results from the imperfection of retrieval devices (equipment failures), errors by servicing personnel, personnel shortages, etc. These internal perturbations distort the linear nature of curve II (area Y), and have a significant influence on the inertia of the system.

In the final stage of transformation of requests to responses (microfilming of relevant documents found in the IRS, retyping of responses, transfer of content of documents to other information carriers, etc.), the rate of change of quality I (as well as I_g in our example) is decreased still further (damps exponentially). In area Z, curve II has its greatest deviation from tangent K, which determines the rate of change of the value of I_g at the initial moment of arrival of requests.

Thus, the intensity of delivery of responses to the consumer is slowed by inertia, which depends both on the operating speed of the IRS used and on the factors determining this speed.

When the open system is closed by a feedback loop, time constant T, as was noted, decreases in comparison to T_{11} by $(1+k_1)$ times. Therefore, the reaction of the closed system to a jump Q_{ob_0} reaches its new value more rapidly. In other words, the time of the transient process T_p of the closed system, during which the output quantity I_g practically approaches the assigned goal, becomes less than the time of transient process T_{p1} of the open system. This is the great advantage of a closed control system from the standpoint of its ability to decrease the length of the transient process.

Thus, analysis of system dynamics allows us to draw our first conclusions, if an information organ performs the function of checking the degree of utilization of information by the consumer and changes its actions holding the system in the required status in correspondence with the results of this checking, the duration of the cycle of effective reference information servicing will be less than the servicing time without feedback.

Comparison of curves I and II shows that a closed system, increasing operating stability, also leads to an undesirable effect. Actually, the stable value of I_g of the closed system is $(1+k_1)$ times less than the similar value of the open system. Therefore, we note that feedback does not assure equality between the values of I_g and Q_{ob}, i. e., between the actual quantity of positive responses satisfying the consumer and the objective requirement for them. This can be explained physically by the assumption made in our model that the consumer utilizes only a portion of the responses I of the information center and therefore the transfer factor case of π of the control object is less than 1. In this particular case, throughout the entire cycle of reference information servicing, static error E_O, defined by the quantity

$$E_1 = Q_{ob}/1 + \kappa_n \kappa_n.$$

is never reduced to 0.

In actual systems, under certain conditions, feedback allows the value of I_g to be brought to the desired value of Q_{ob} by restructuring the internal strucrure of individual links. This is achieved by improving the qualitative indicators of the IRS and in particular by making changes in the structure,

composition and theme of the information files, the organization of labor, i. e., by increasing the transfer factors k_{μ} and k_p.

One effective means of decreasing error signal E to 0 is control on the basis of the integral (where the transfer function is $H_{\kappa} = 1/p$). Introduction of an integral servicing law of incoming requests is similar to the concept of "accumulation of experience." This control calls for integration of the error signal which arises during the time of the transient process. From the physical standpoint, this means that the information organ accumulates, stores and "remembers" all requests encountered earlier, and each new input signal is compared with the information as stored in "memory." Based on this work, we can compensate for the inertia of the system, and the control action is developed to the limit, corresponding to the maximum value of 1 (full relevance of responses).

We can conclude from the above that if the coefficients case of κ and k_{π} do not change during the process of functioning of our system, even when there is feedback in the stable mode (where $t \geq T$) we cannot achieve ideal "tracking" of objective requirement Q_{ob} at the output. Here we have arrived at another, no less important conclusion, following from our analysis of the dynamics of the model.

The introduction of a feedback loop decreases the duration of the reference information cycle, stabilizes the basic parameters but cannot reduce the error between the objective requirement for information and the capabilities of the information organ to 0 unless the organ overestimates its activity in the control process. Together with this, feedback creates realistic conditions and prerequisites for increasing the level of organization of the system. This is explained by the fact that a closed information system allows its behavior to be compared for one or more operating cycles and the necessary adjustment of operating parameters to be made, making it possible to change a tendency in its own characteristics, i. e., this sort of system is well adapted for self-improvement on the basis of information received from the consumer. This means that this system is capable of "learning".

On the contrary, an open information system is not capable of self-testing and if problems arise in the information process there is no feedback signal in the system to indicate the divergence between desired and actual behavior of the system and introduce the required correction to adjust its operation.

Here we should recall the comments of G. M. Dobrov in [14]: "Without this -- without the required feedback -- the system operates "blind", and cannot be effectively controlled." In another work [12], A. V. Kozenko and A. N. Polovinchik state: "In order to increase the effectiveness of information retrieval, the accuracy and completeness of responses output, it is necessary to provide stable, dynamic feedback between information consumers and the IRS."

Obviously, we can state with good reason that individual actual "information center -- information consumer" type systems fall in the class of learning (self-tuning) systems.

Without discussing this interesting, independently significant problem in detail, we note that increasing the level of organization of a system results from the same factors which we have mentioned repeatedly -- changes in the transfer functions of the direct and feedback elements, i. e., changes in the structure, composition and theme of files, selection of more effective and rapid IRS, improvement of operating methods and interaction between individual links, etc.

Thus, we can draw our third important conclusion.

An information organ can provide optimal operation of the "information center -- information consumer" system only if it is adjusted to changing external conditions on the basis of the results of control and behavior of the controlled object, i. e., on the basis of accumulated experience.

With this, we conclude our brief analysis of one particular information system.

All of the arguments which we have presented lead us to the following conclusions:

1. The values of the basic parameters (T, T , T_π, k_1, k , k_π, α) and the quantative characteristics Q_{ob}, I, E, I_g gives us a complete idea of the efficiency of the system as a whole and its individual links, provides the scientific basis for determination of means of increasing the effectiveness of the system, i. e., for production of decisions providing the required operating characteristics.

2. Although the predictions and solutions presented here in mathematical form are rather well known in the practice of information activity, they are little used in specific problems of control of information systems.

3. The cybernetic approach to the study of information systems is not exhausted by quantative analysis alone, but allows us to understand the qualitative aspects of the internal structure of these systems.

4. In evaluating the operating quality of an information system, we must deal with contradictory requirements. For example, the requirement to decrease the error signal E, indicating imperfect control, contradicts the requirement to reduce the length of the effective information servicing cycle; the requirement to decrease the value of control action I, i. e., to decrease material expenditures on the creation and functioning of the information organ, contradicts the requirement for improved system dynamics, etc.

This makes it clear that depending on the value attached to control accuracy, operating speed, etc. in a given system, the relative weights of quantities E, I, I_g, T and k_1 will change. We might note that the desire to develop high peak control actions I causes an increase in the information file size, increasing the cost of equipment, complicating the structure of the information organ. This in turn is unavoidably reflected on the inertia of the information organ, which becomes significant.

On the other hand, we must consider the inertia of the information consumer (in our example, we arbitrarily assumed that $T_\pi=0$.

High inertia of the consumer may cancel the improvement in system dynamics hoped for when operational expenditures are increased to increase signal I.

Thus, in an actual problem in selecting a program of actions allowing a goal to be achieved with confidence and economy, we must consider the interrelationship of parameters and their influence on system dynamics; we cannot ignore the numerical values of α, A, k , k_π and T.

5. Measurement in an actual system of the variables Q_{Ob}, I and I_g at least in principle represents no great difficulties. Determination of the values of A, α, k , k_π, and k_{OC} represents significant difficulties. Qualitative estimation of these quantities can be performed by analyzing experimental data on the basis of a study of specific information systems.

6. The cybernetic approach to the study of information systems can provide a better understanding of the experience, intelligence, intuition and foresight which are used at the present time to select strategies of control of information systems.

* * *

In conclusion, we note that we have studied an idealized, greatly simplified system in this article. It was assumed that the system included no perturbing actions influencing the output signal. Only the influence of a sudden input action was studied, although there is obvious interest in other functions of the input action -- linear, sinusoidal and, of course, random. For a number of reasons, the study of random functions in information systems is of particularly great interest.

However, in studying the reaction of the information system to simple inputs, we can explain many phenomena observed in the practice of information work.

We have desired to show that even a greatly simplified mathematical model of an information system raises the curtain before the complex interaction of various components of the system, bringing researchers to a new level of analysis of facts observed in practice.

BIBLIOGRAPHY:

1. Gitis, E. I., Danilovich, G. A., Samoylenko, V. I., Tekhnicheskaya Kibernetika [Engineering Cybernetics], SOV. Radio Press, 1968.
2. Milsum, J., Analiz Diologicheskikh Sistem Upravleniya [Analysis of Biological Control Systems], MIR Press, 1968.
3. Anokhin, P. K., Physiology and Cybernetics, Filosofskiye Voprosy Kibernetiki [Philosophical Problems of Cybernetics], Moscow, 1961.
4. Bionics and Biocybernetics, Zinatne, Riga, 1968.
5. Levada, Yu., Cybernetic Methods in Sociology, Kommunist, 1965, No 14.
6. Lange, O., Vvedeniye v Ekonomicheskuyu Kibernetiku [Introduction to Economic Cybernetics], Progress Press, 1968.
7. Petrushenko, L. A., Printsip Obratnoy Svyazi [The Principle of Feedback], Moscow, Mysl' Press, 1967.
8. Popilov, L. Y., The Problem of Qualitative and Quantative Evaluation Criteria of In[illegible]ion Flows and the Difficulty of Processing of Information Sources, Nti, [illegible], Series 2, No. 3, p 3-6.
9. Klaus, G., K[illegible]ernetika i Filosofiya [Cybernetics and Philosophy], Moscow, 1963.
10. Shekhurin, D. Ye., The Problem of the Criterion of Information Requirements, Nti, 1969, Series 1, No. 5, p 3-7.
11. Problems of the Development of Mechanized Information Retrieval Systems for a Central Reference Information Fund on Chemistry and the Chemical Industry, Niitekhin, No. 11, 1968, p 58.
12. Kozenko, A. Z., Polovinchik, A. N., Effektivnost' Nauchno-tekhnicheskoy Informatsii [Effectiveness of Scientific and Techical Information], Moscow, Ekonomika Press, 1967, 176 pages.
13. Goodrum Charles A., The Reference Factory Revisited., Libr. J., 1966, 93, No 8, 1577-1580.
14. Doblov, G. M., Nauka o Nauke [The Science of Science], Naukova Dumka Press, Kiev, 1966, p 269.